PASSIVE ACOUSTIC DETECTION AND MONITORING OF ENDANGERED WHALES IN THE ARCTIC (BEAUFORT, CHUKCHI)

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ECOSYSTEM OBSERVATIONS IN THE CHUKCHI SEA: BIOPHYSICAL MOORINGS AND CLIMATE MODELING

ANNUAL REPORT

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Executive Summary

Through an Inter-Agency agreement (IA) between the National Marine Mammal Laboratory (NMML) and the Minerals Management Service (MMS), NMML is conducting a dedicated multi-year study of the distribution and relative abundance of endangered whales in the Chukchi Sea Planning Area and relate variation in those parameters to oceanographic conditions, indices of potential prey density, and anthropogenic activities. This annual report covers the period between February 2010 and January 2011.

The major activities during this period consisted of the preparation for and execution of the Chukchi Sea Acoustics, Oceanography, and Zooplankton (CHAOZ) cruise from 24 August through 20 September 2010. The cruise took place on the chartered fishing vessel F/V *Alaskan Enterprise*. Twelve scientists and observers participated on the CHAOZ cruise.

Since the completion of the cruise, all data have been stored, organized, and analyses begun (where possible), and the preliminary results are detailed below. In addition, work has begun on the modeling component of the project, which aims to predict the impact of climate change on the sea-ice characteristics and physical variables in the Chukchi Sea.

Introduction and objectives

The western Arctic physical climate is rapidly changing. The summer minimum sea ice extent in 2007 and 2008 covered an area which was 37% less than that of two decades ago. The speed of these changes was unexpected, as the consensus of the climate research community just a few years ago was that such changes would not be seen for another thirty years. As sea temperature, oceanographic currents, and prey availability are altered by climate change, changes in baleen whale species composition, abundance, and distribution are expected (and evidenced already by local knowledge and opportunistic sightings). In addition, the observed northward retreat of the minimum extent of summer sea ice has the potential to create opportunities for the expansion of oil and gas-related exploration and development into previously closed seasons and localities in the Alaskan Arctic. It may also open maritime transportation lanes across the Arctic adding to the ambient noise in the environment. This combination of increasing anthropogenic impacts coupled with the steadily increasing abundance and related seasonal range expansion by the bowhead, gray, humpback, and fin whales, indicates that more complete information on the year-round presence of large whales is needed in the Chukchi Sea planning area. Timing and location of whale migrations may play an important role in assessing where, when, or how exploration or access to petroleum reserves may be conducted to mitigate or minimize the impact on protected species.

This study has four component projects: oceanography, passive acoustics, zooplankton, and climate modeling. Each component project is a technical discipline and will be coordinated by a Project Leader with extensive experience in that discipline. Passive acoustic moorings, deployed concurrently with bio-physical moorings will provide previously unattainable year-round assessments of the seasonal occurrence of bowhead, humpback, right, fin, gray, and other whales in this planning area and their response to environmental changes (including oceanographic conditions, climate, indices of potential prey density, and anthropogenic activities). Moorings permit observations during long periods when ice covers the region, especially during the critical spring and early summer periods when spring phytoplankton blooms occur. Such measurements are virtually impossible to obtain from ships, because of the relatively short duration of cruises and severe limitations in the availability of ships able to work in ice-covered seas.

The overall goal of this multi-year IA study is to document the distribution and relative abundance of bowhead, humpback, right, fin, gray, and other whales in areas of potential seismic surveying, drilling, construction, and production activities and relate changes in those variables to oceanographic conditions, indices of potential prey density, and anthropogenic activities.

The specific objectives are:

1. Assess the year-round seasonal occurrence of bowhead, gray, and other whale calls in the Chukchi Sea.
2. Estimate relative abundance of these whales.
3. Obtain two full years of biophysical measurements on the shallow Chukchi shelf utilizing moorings at three sites, and collect hydrographic and lower trophic level data during deployment/recovery of the moorings.

4. Evaluate the extent to which variability in environmental conditions such as sea ice, oceanic currents, water temperature and salinity, and prey abundance influence whale distribution and relative abundance.
5. Run the National Center for Atmospheric Research (NCAR) climate model (Community Climate System Model: CCSM) for future projections using the sea ice extents from 2007/2008 as initial conditions.
6. Analyze multiple ensemble members from the NCAR model and other IPCC models to assess the future variability of sea ice cover and extended sea ice free seasons during fall for the Chukchi Sea.
7. Evaluate whether changes in seasonal sea ice extent are resulting in a northward shift of Bering Sea cetacean species such as fin, humpback, and North Pacific right whales.
8. Provide long-term estimates of habitat use for large whale species and compare this with predictions about annual ice coverage to establish predictive variables that describe large whale occurrence.

Cruise activities and summary

The CHAOZ cruise took place from 24 August through 20 September aboard the F/V *Alaskan Enterprise*. Twelve scientists participated in the survey. A total of 51 CTD and plankton tow stations were completed, 30 long-term oceanographic and acoustic moorings were deployed, over 1,475 miles were visually surveyed, and 102 sonobuoys were deployed. Please see the attached 2010 CHAOZ cruise report for a full summary of activities and accomplishments made during the cruise.

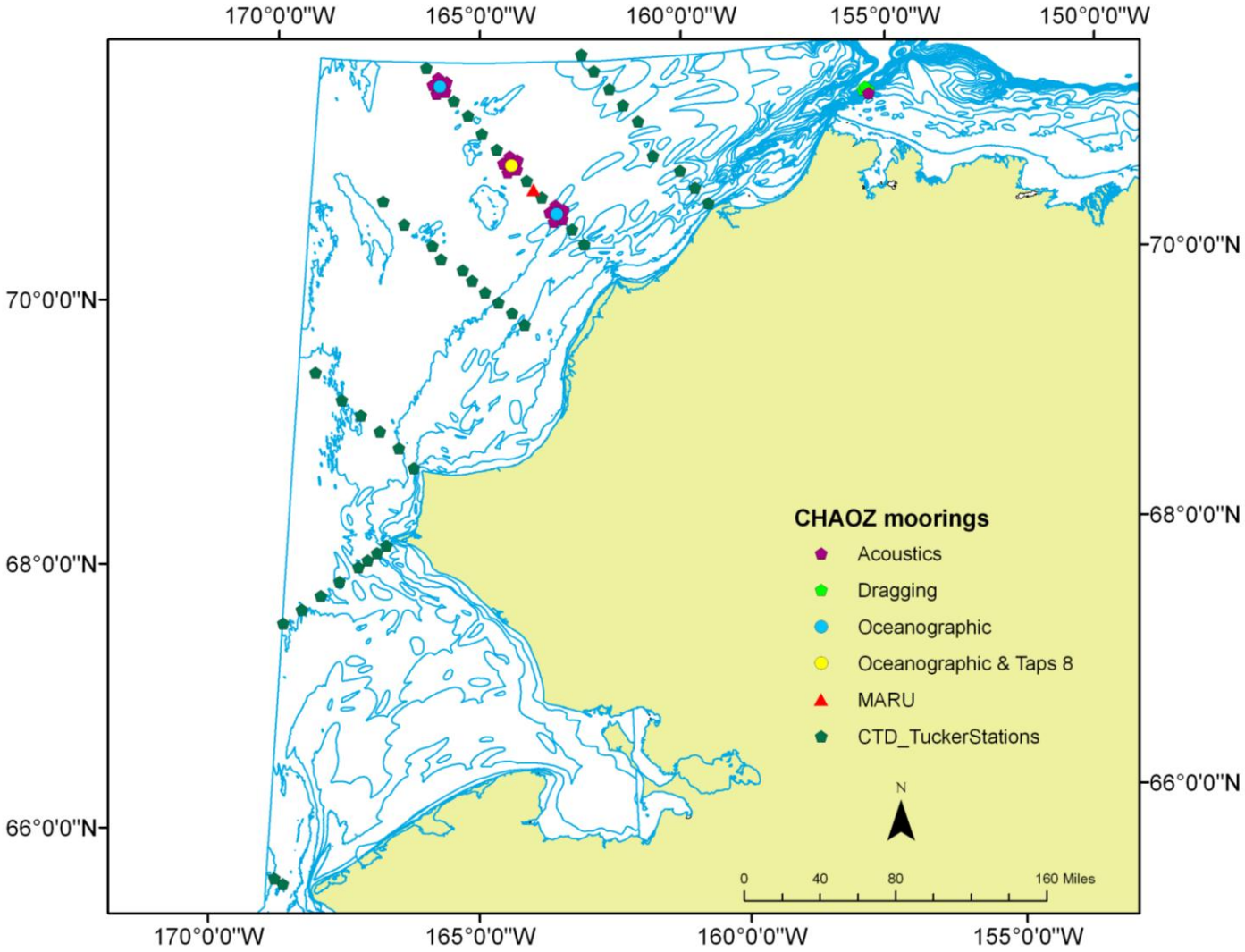

Figure 1. Map showing CTD/plankton tow stations and mooring locations.

ACOUSTICS COMPONENT

Preliminary results

NMML Long-term moorings:
The data from the long-term passive acoustic recorders (Figure 1) will not be available for analysis until they are retrieved in one year. Modifications to existing array localization code will be completed in the spring.

Sonobuoys:
A total of 102 sonobuoys were deployed during the cruise. A preliminary analysis of species detected was conducted and the results are shown in Figures 2 and 3. The most commonly detected species were fin whales (*Balaenoptera physalus*), bowhead whales (*Balaena mysticetus*), and walrus (*Odobenus rosmarus*). Refer to the cruise report for a more detailed description.

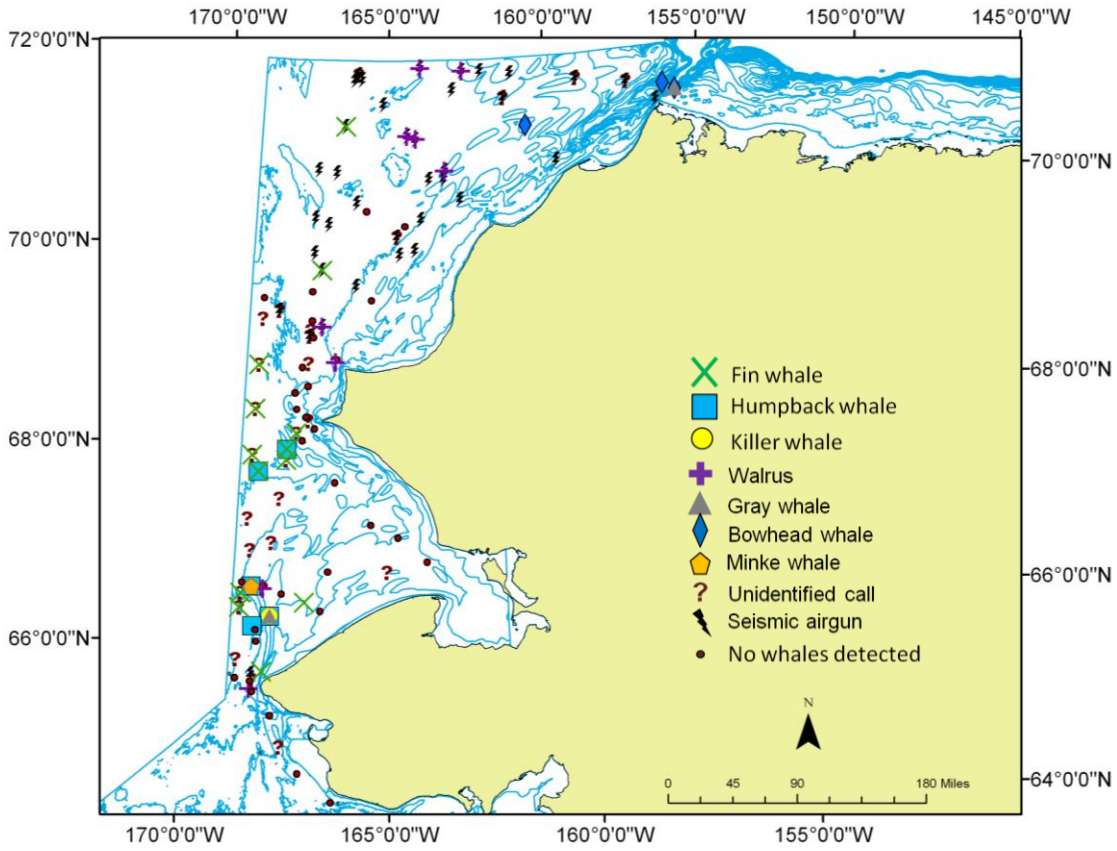

Figure 2. Sonobuoy deployment and acoustic detections in the Chukchi Sea.

2011 preparations and analysis plans

The vessel contract for the 2011 field season was submitted in early December 2010, and preparations for the 2011 cruise are already underway. Equipment purchase orders are being drafted and will be submitted within the month. The dragging winch was repaired this winter, and will have some additional modifications done in the spring.

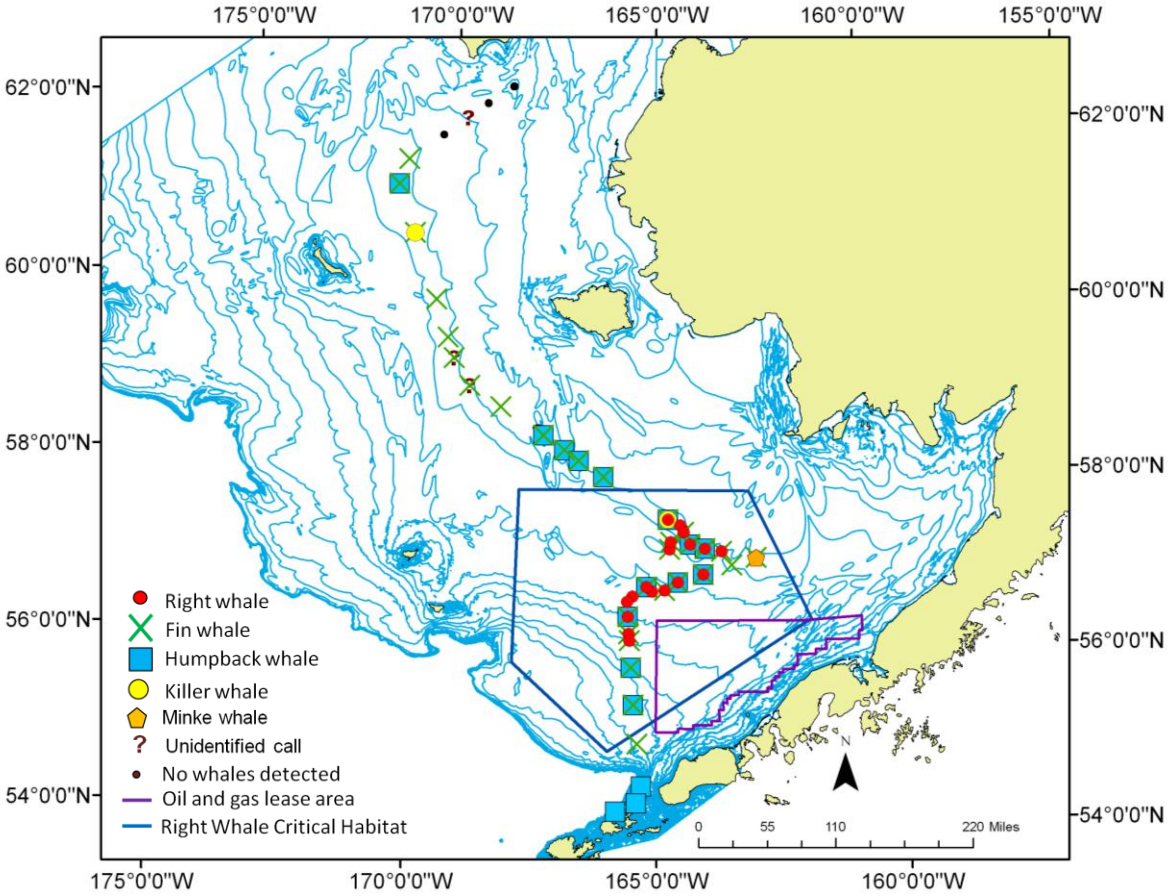

Figure 3. Sonobuoy deployment and acoustic detections in the Bering Sea.

We designed an acoustic analysis program, implemented in Matlab, which will be used for all data analysis (see Appendix 1). Using this program, spectrograms are generated of all sound files, and are then analyzed for presence of desired species or call type. Current short-term plans include an in-depth analysis of real-time sonobuoy recordings made during the cruise. When possible, localizations of calling whales will be run to produce a finer scale analysis of whale distribution within the Chukchi and Bering Seas.

OCEANOGRAPHIC COMPONENT

Preliminary results

Long-term moorings:
We successfully deployed seven moorings (Figure 1), which will measure biophysical data (temperature, salinity, current speed and direction, nitrate, light, ice thickness) at three sites in the Chukchi Sea along the Wainwright line. The data from the long-term sensors will not be available for analysis until they are retrieved in one year.

Shipboard measurements:
Temperature, salinity and nutrients were measured on each hydrographic line (Figure 1). First order processing has been completed for temperature and salinity in preparation for a poster at the Alaska Marine Science Symposium meeting in January (Figure 4).

Satellite Remote Sensing:
Preliminary processing of relevant satellite remote sensing products was begun during this period (Figure 5). We are investigating the value of images showing sea surface temperature, true ocean color, and satellite-derived chlorophyll.

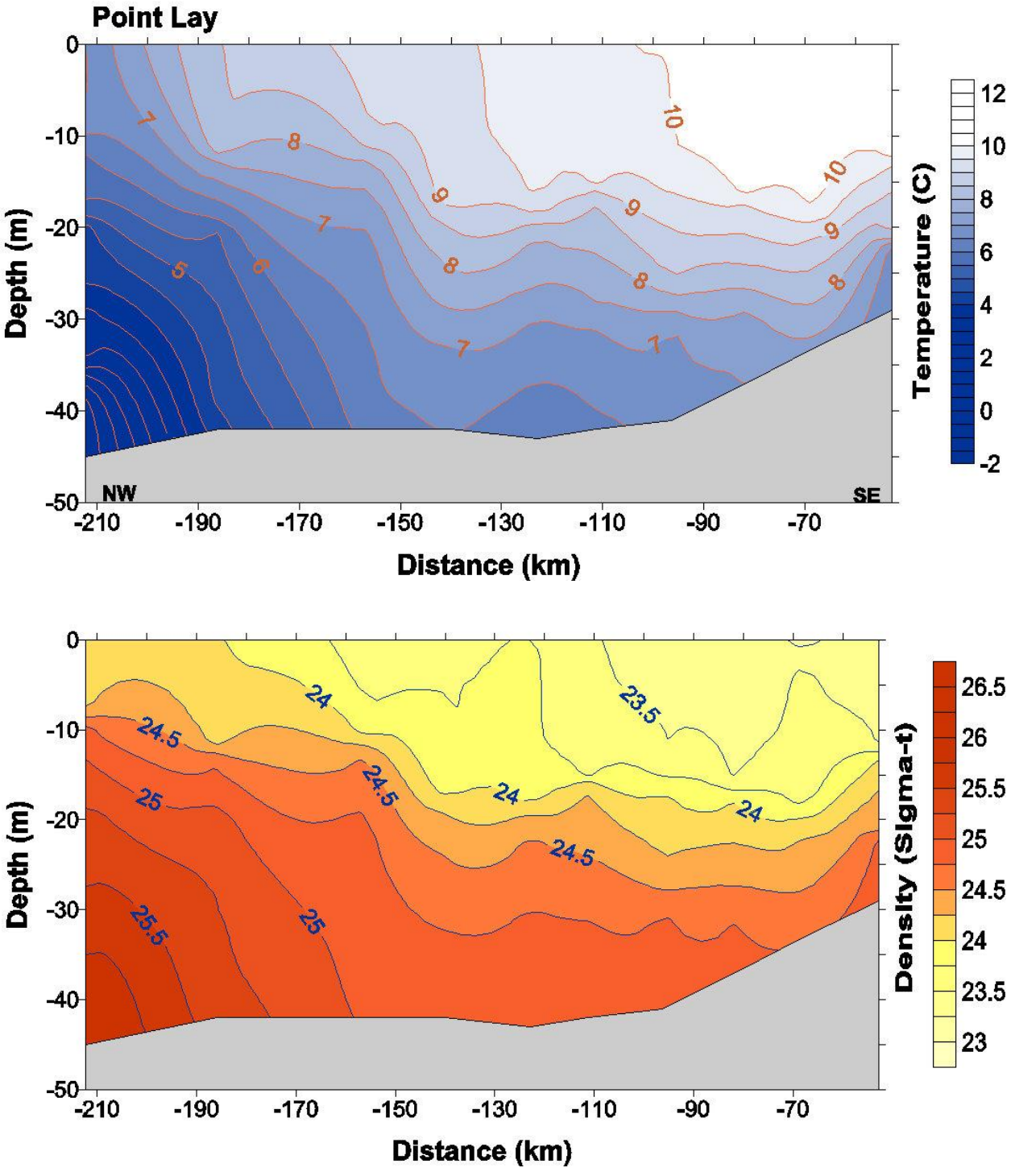

Figure 4. Preliminary temperature (top) and density (bottom) data from transect off Point Lay.

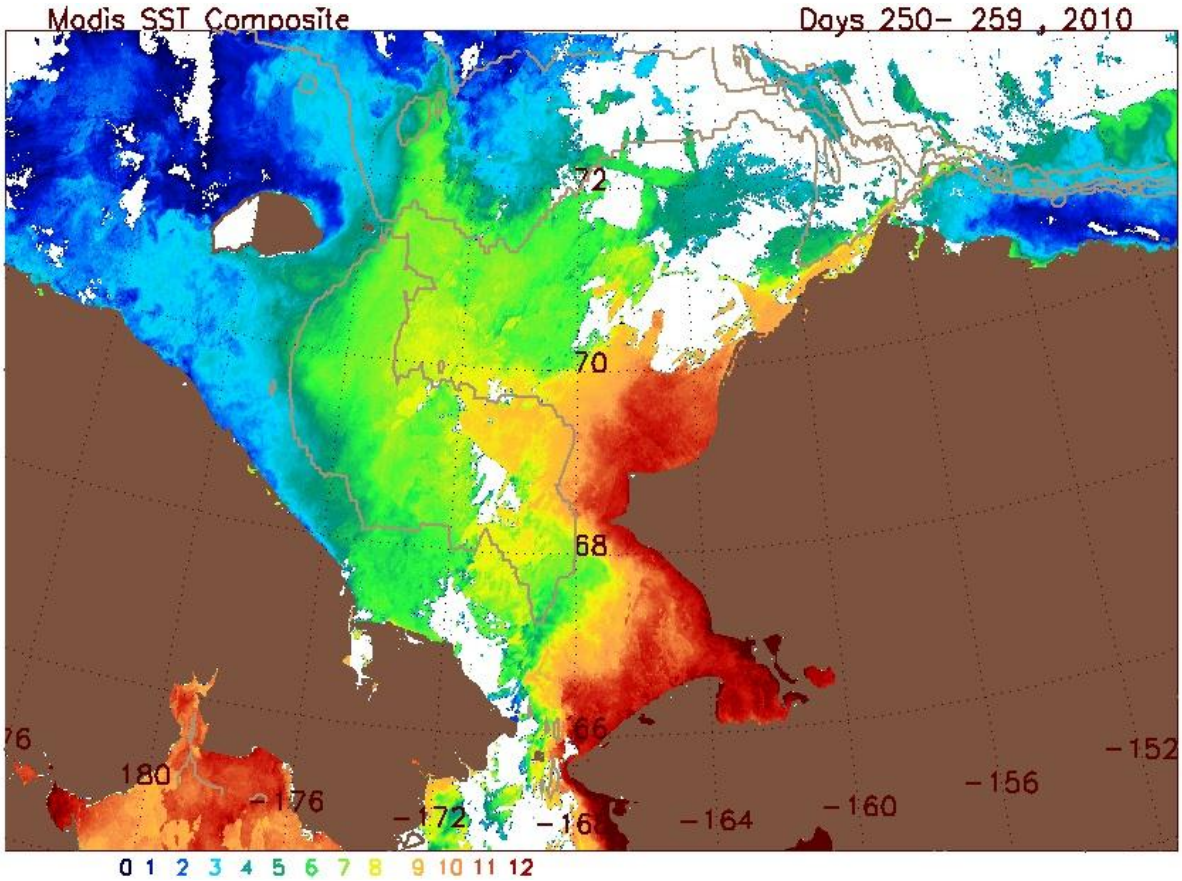

Figure 5. Sea surface temperature composite image (Julian Days 250 – 259; 7 – 16 September) of the Chukchi Sea.

2011 preparations and analysis plans

Data Analysis:
Once the salinity samples are run on a laboratory salinometer, the final processing of the temperature and salinity data from the CTD and (2) SeaCats will be completed. Final hydrographic data from the cruise will be uploaded to the database by February 1, and hydrographic sections will be completed. Nutrient samples collected during the cruise have been processed. They will be integrated into the hydrography files before submission to the database.

We are in the process of comparing the results from the CTD cast with the data collected by the SeaCAT on the net tows. Once the final quality control of all the data is completed, we will examine water properties and identify probable sources of water. We are also analyzing a variety of satellite images which will provide further information on spatial scales for temperature and chlorophyll.

Cruise Preparation:
We have begun preparation for the summer cruise of 2011. This includes purchase of equipment and repair of the CTD which was damaged in 2010. It is awaiting the transfer of funds to complete repairs. Personnel for the upcoming cruise have been selected and notified. Further improvements/modifications are being made to the laboratory van purchased for this project to make the best use of that space. Mooring designs have been finalized and purchase and calibration of the remaining sensors have begun. This year a second oceanographic winch with conducting cable will be carried by the ship in case the primary winch fails, along with a second deck unit. Routine maintenance to that winch will occur in the second quarter.

ZOOPLANKTON COMPONENT

Preliminary results

TAPS Long-term moorings:
A TAPS-8 was successfully deployed at Station WT6 (Figure 1, yellow dot) and was programmed to sample every 30 mins. Data from the instrument will not be available for analysis until after it is retrieved during the 2011 CHAOZ cruise (August/September).

Shipboard measurements:
Preserved zooplankton samples (0.333mm mesh and 0.153 mm mesh) from the Tucker sled were sent to Poland for processing in November. It is anticipated that the data will be returned by May 30. After applying our standard QC/QA procedures, those data will be ready for uploading into our database and analysis. Chlorophyll samples from the hydrographic casts were frozen at sea and are in Seattle awaiting analysis. The TAPS-6 was mounted on the Tucker Sled and successfully operated in "cast mode" to collect zooplankton volume backscatter on approx. 50 tows along the 5 cardinal sampling lines (Figure 1).

2011 preparations and analysis plans

TAPS-8 Design and construction:
A contract was successfully let to Mr. Charles Greenlaw (one of the original TAPS engineers) to design and advise us on the construction of several new TAPS-8 instruments with updated electronics. A team of 3 NOAA scientists and engineers at PMEL and AFSC worked with Mr. Greenlaw on the project. A project schedule was established, the design concept was finalized, and preliminary designs for printed circuit boards were delivered to NOAA for checking. In addition, NOAA team members identified a commercial manufacturer who could supply all of the necessary transducers so that we do not have to make any of our own, greatly simplifying the process. Procurement of calibration instrumentation was also begun during this period. In 2011 a second contract will be let to obtain technical expertise necessary to establish calibration expertise here within our laboratory.

Data Analysis
All of the TAPS-6 cast mode data have been initially processed using a single scattering model (fluid sphere). Sections of estimated total zooplankton biovolume were constructed for presentation at the AMSS meeting (Figure 6). Final processing of the data will take place after the first of the year, when the TAPS-6 has a post cruise calibration. Final analysis will subject the data to a two-model inverse solution (fluid sphere and Distorted-Wave Born Wave Approximation) to simultaneously estimate scattering attributed to copepod-like and euphausiid-like (elongate) scatters. In addition, during the coming year, we will work to modify the TAPS-8 analysis code to perform the two-scattering model inverse.

Cruise Preparation:
As soon as the amended MOU is signed, we will begin to make purchases necessary for the upcoming field season. Preliminary discussions were held with the manufacturer of our winch regarding modifications necessary to make it easier to repair and maintain at sea. The manufacturer is prepared to make those repairs this spring. Personnel for the upcoming cruise have been selected.

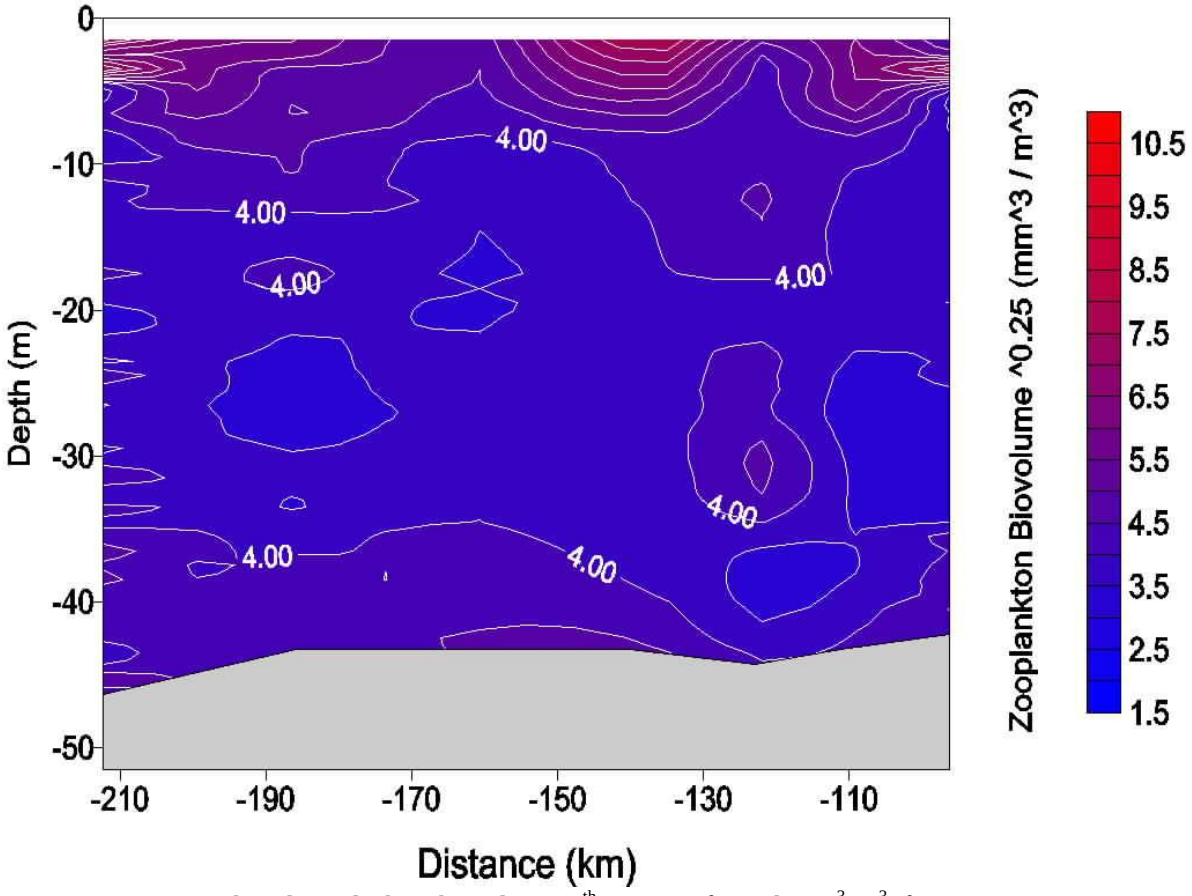

Figure 6. Estimated total zooplankton biovolume (4^{th} root transformed; $mm^3\ m^{-3}$) from Point Lay transect. Note that the first three stations were not sampled due to rough weather.

OCEAN NOISE AND REAL-TIME PASSIVE ACOUSTIC MONITORING

Preliminary analysis

A mutual decision was made by NMML and Bioacoustics Research Program (BRP) at Cornell University to postpone deployment of their auto-detection buoy until the 2011 field season. However, during the 2010 CHAOZ cruise, a double capacity MARU was deployed. The data from this long-term mooring will not be available for analysis until it is retrieved in one year on the 2011 CHAOZ cruise.

2011 preparations and analysis plans

The Cornell contract, with an updated proposal and budget was submitted to contracting in late winter. Noise modeling will begin after the contract is awarded.

CLIMATE MODELING COMPONENT

Preliminary results

We participated in the Arctic synthesis study workshop "Rapid change in Arctic Sea Ice: Assessing drivers and future trajectories" during which both M. Wang and J. Overland gave presentations at the workshop. Very active discussions were going on during the workshop. A manuscript about future climate projections by IPCC AR4

models is in preparation, and will be submitted by the end of November. The manuscript will provide a suite of variables important to the marine ecosystem of the Bering and Chukchi Seas. An initial website of the projections based on 6-models for the Bering Sea (variables include sea ice extent, SST, SAT, SLP, wind (UV) and precipitation) has been created and is running under the "Bering Climate" web site (http://www.beringclimate.noaa.gov/projections.html).

Significant meetings held or other contacts made

5/25/10: On-site visit by sonobuoy suppliers Jeff Leonhard, Theresa Yost, and Todd Mequet at NMML campus.

10/7/2010: Berchok and Crance met with Sue Moore, Kate Stafford, and Manolo Castellote to discuss analysis plans for the upcoming quarter.

12/3/10: Conference call among Berchok, Crance, Chuck Monnett, Chris Clark, and Phil Clapham regarding status update and upcoming contracts.

Presentations

Berchok, C.L., J. Crance, B. Rone. 2010. "North Pacific Right Whale Survey Acoustics". 26 May 2010. Sonobuoy conference at the Naval Air Station, Whidbey Island, Oak Harbor, WA.

Berchok, C.L., S. Moore, J. Napp, J. Overland, and P. Stabeno. 2011. "Bringing CHAOZ to the Arctic". Alaska Marine Science Symposium, 17-21 January 2011. Anchorage, AK.

Crance, J.L., C.L. Berchok, A. Kennedy, B. Rone, E. Küsel, J. Thompson, and P.J. Clapham. 2011. "Visual and acoustic survey results during the 2010 CHAOZ cruise". Alaska Marine Science Symposium, 17-21 January 2011. Anchorage, AK.

Delarue, J., Mellinger, D.K., Stafford, K.M., and Berchok, C.L., 2010, "Where do the Chukchi Sea fin whales come from? Looking for answers in the structure of songs recorded in the Bering Sea and Western N. Pacific". The 159th meeting of the Acoustical Society of America, 19-23 April 2010. Baltimore, MD.

Napp, J. and P. Stabeno. 2011. "CHAOZ: CHukchi Acoustics, Oceanography, and Zooplankton, Part II". Alaska Marine Science Symposium, 17-21 January 2011. Anchorage, AK.

Overland, J.E. 2010. "Hot Arctic-Cold Continents: Climate Impacts of the Newly Open Polar Sea." Rapid changes in Arctic sea ice: Assessing drivers and future trajectories workshop, 6-8 October 2010. Fairbanks, AK.

Wang, M. 2010. "Melting pond in the Arctic Sea ice: How much can we learn from the NPEO?" Rapid changes in Arctic sea ice: Assessing drivers and future trajectories workshop, 6-8 October 2010. Fairbanks, AK.

Wang, M., J.E. Overland, and P. Stabeno. 2011. "Future status of the Chukchi Sea seen from global climate models". Alaska Marine Science Symposium, 17-21 January 2011. Anchorage, AK.

APPENDIX 1.

The SoundChecker program was developed in-house in response to the sheer magnitude of passive acoustic data recordings that need to be analyzed, the enormous overlap of the acoustic repertoires of many Alaskan marine mammal species, and the lack of any semblance of a stereotyped call for most of the species.

We are finding it extremely difficult to come up with autodetection parameters that effectively catch the majority of a particular call type in all locations for all recorder types and seasons, without catching a majority of calls from other species as well. The amount of effort required to effectively ground truth a particular autodetection run, in addition to still having to process a majority of the files, has led us to just use a brute force method of manual analysis. However, the SoundChecker program has the option of running on data sets that have already been run through an autodetector (or set of autodetectors).

The trouble with any spectrogram based sound analysis program is the amount of computational time needed to generate the spectrograms. This time increases as the frequency band of interest increases. SoundChecker, written in the Matlab programming language, operates on image files (Portable Network Graphics (PNG) format) that can be generated ahead of time (typically overnight), so no time is wasted waiting for the spectrogram to appear during the analysis sessions.

Figure A1 shows the interface window for the SoundChecker program. It consists of the spectrogram image whose title indicates the data/time/location of the sample, an information bar that shows what species/call type/analysis interval is being used as well as a counter to protect the analyst's sanity, and a variety of action button. In use all of the time are the Yes/No/Maybe buttons. Once the analyst decides if a species or call type is present they select one of those buttons and the program jumps to either the next image file for No/Maybe answers or the first image file of the next time interval for Yes answers. There is also an option to go back to a previous image if a correction is needed. If a shorter analysis interval is desired, it is simple to re-run that recorder at the shorter interval – the images already assigned to Yes/No/Maybe will be skipped over, allowing for faster re-analysis.

Since many sounds are difficult to determine just visually, there is a set of playback buttons that can be used on sections of the image file selected by drawing a box with the cursor. To this end, there is also a set of zoom buttons that allow for more detailed (or with better contrast) views of selected sections of the image. The zoom-save button allows an image file and its related wave file clip to be saved to our expanding library folder of known species calls and our increasingly expanding folders of unknown signals. Furthermore, there is a review mode button (See Figure A2) that lets the analyst jump back to a specific time/date image and retain the playback/zoom functions without altering the Yes/No/Maybe responses. This is particularly helpful during the many meetings we hold to try and determine the source of many of the signals detected.

So far, this method is proceeding faster than expected, with the worst case recorders taking around 3 weeks for one analyst to process a year's worth of data. The benefit we are finding with this method is that because we can view an entire 3-4 minute chunk of data at a time, we are getting a good overview of all the call types that are out there – not just those in a particular frequency band or those with particular characteristics. Furthermore, viewing the call in this longer-term context is extremely helpful for making decisions on the signal source.

Because the results from this analysis are in a consistent form, further analysis of the results can be automated, including plot generation and correlation to other biophysical parameters.

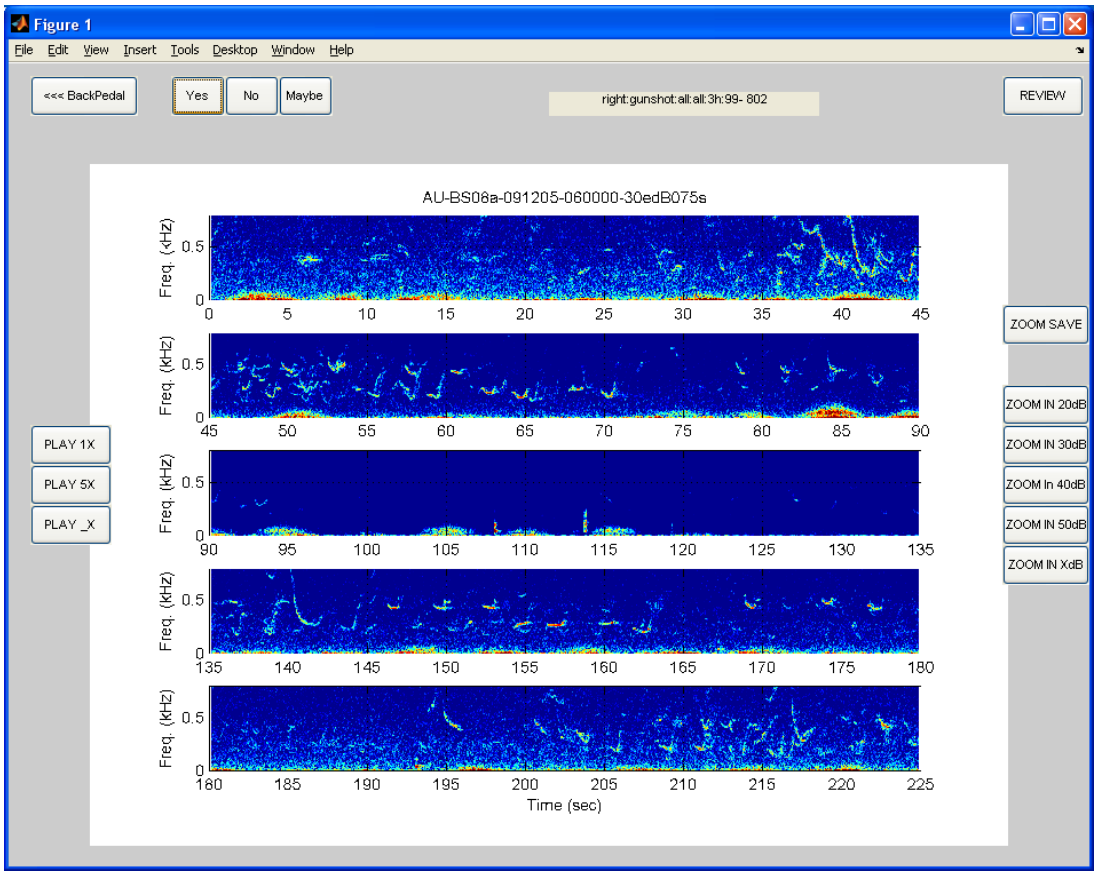

Figure A1. SoundChecker analysis interface. Spectrogram shown is for a recorder in the Bering Sea deployed in 2009 and represents 225 s of recordings starting at 06:00:00 UTC on 05 Dec 2009. The upper information bar shows that this analyst is looking for right whale gunshot calls in 3 hour analysis intervals and is 802 spectrograms into their analysis session. Present are bowhead whale and ice seal calls. SoundChecker was written in the Matlab programming language.

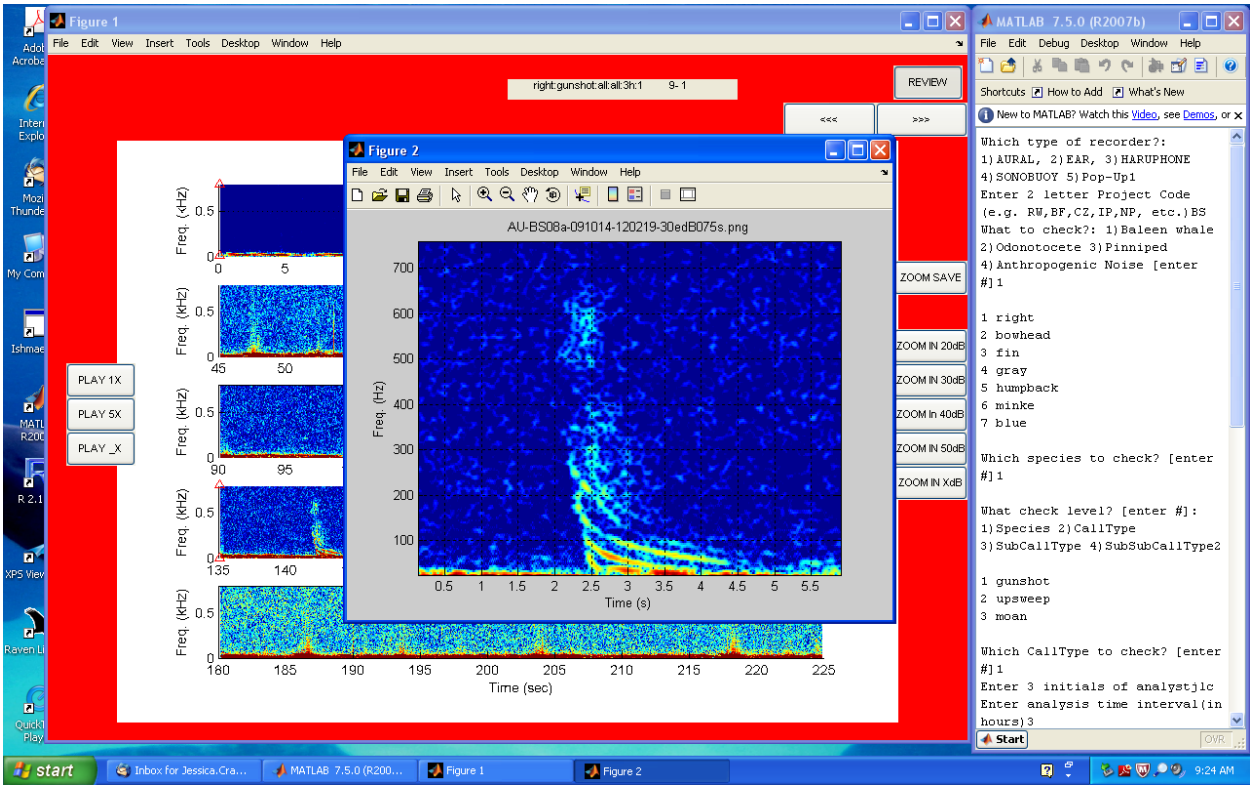

Figure A2. SoundChecker analysis interface in review mode with a zoom option selected. Spectrogram shown is for a recorder in the Bering Sea deployed in 2009. The zoom clip shows a single gunshot call occurring at approximately 12:02:21 UTC on 14 Oct 2009. SoundChecker was written in the Matlab programming language.